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MECHANICAL AND PHYSICAL BEHAVIOUR OF SHORT AND RANDOMLY ORIENTED BANANA PSEUDO-STEM FIBER REINFORCED EPOXY COMPOSITE

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ABSTRACT

A study has been carried out to investigate the mechanical and physical characteristics of short, treated and randomly oriented Musa Acuminata x Balbisiana Colla (also known as *Pisang Awak*) pseudo-stem fiber reinforced epoxy composite. The composite was fabricated by using hand lay-up method with three different banana fiber weight compositions of 5 wt%, 10 wt% and 15 wt%. The banana fiber was treated with 5 % of NaOH. The increment in fiber weight percentage has contributed to composite characteristics since the highest fiber percentage which is 15 wt% of banana pseudo-stem fiber content shows the highest strength in maximum stress, Young's modulus, flexural strength, impact strength, hardness and water absorption percentage with average value of 34.121 MPa, 1150.098 MPa, 20.935 MPa, 0.343 J/mm^2, 80.8 Shore hardness and 1.536% for water absorption respectively. Fiber and matrix interaction was observed using Scanning Electron Microscopy (SEM). This study shows the potentiality of banana pseudo-stem fiber in green composite technology and allows production of many products.

Keywords: Banana Fiber; Natural Fiber; Reinforced Composite; Random Oriented, Epoxy.

INTRODUCTION

Natural fiber is one of the most common materials used to produce natural composite. Natural fiber offers renewability, abundance source and lower cost and have many advantages compared to glass fibers, for example they have low density, are recyclable and biodegradable (Sapuan et al., 2006; Mallick, 1993). Additionally, they are renewable raw materials and have relatively high strength and stiffness.

In year 2011, banana is the second most important commercial fruit crops in Malaysia which have 24,223 ha production areas with production of 334,302 metric tonnes (Ministry of Agriculture and Agro-Based Malaysia, 2011). Musa Acuminata X Balbisiana Colla (Awak) usually known as *Pisang Awak* is one of the banana types in Malaysia has been chosen because of its size and availability, to get result uniformity on specified species. Besides, banana pseudo-stem, bunch and leaf have become a waste material after the fruit was harvested. Table 1 and Table 2 show the mechanical properties and botanical composition of banana fiber.

The epoxy resin has been selected as the composite matrix because it has high mechanical and thermal properties, high water resistance; long working times available and low cure shrinkage (Mohanty, 2005). Epoxy resins are widely used because of their versatility, high mechanical properties, and high corrosion resistance. Epoxy resins are also favored for their simple cure process that can be achieved at any temperature between 5 °C to 150 °C (Barbero, 1999).

Chemical treatment with Sodium Hydroxide (NaOH) removes moisture from fibers, thereby increasing their strength (Chandramohan et al., 2011). The chemical treatment also enhances the flexural rigidity of the fibers, removes all impurities adjoining the fiber material and also stabilizes the molecular orientation.

The density of the okra, sisal and banana fiber reinforced polyester composites decreases with increasing volume fraction of fiber because the fiber density is lower than the matrix, thereby the density of composite decreases with increase in fiber content (Srinivasababu et al., 2009). The variation of tensile strength and tensile modulus also increases as the percent volume fraction of fiber increases (Srinivasababu et al., 2009).

The objectives of this study are to investigate the mechanical and physical properties of banana pseudo-stem fiber reinforced epoxy composite by the effect of different fiber weight percentage. Mechanical and physical properties were investigated by tensile test, flexural test, impact test, hardness test, water absorption test and Scanning Electron Microscopy (SEM). The study on this waste material will provides another platform for this natural fiber product extracted from banana pseudo-stem to be useful and become one of the solutions for reducing environmental problems.

Table 1. Mechanical properties of natural fiber (Idicula et al., 2006).

Fibers	Diameter (μm)	Density (kg/m^3)	Tensile strength (Mpa)	Tensile modulus (Gpa)	Elongation at break (%)	Flexural modulus (Gpa)	Lumen size (μm)	Micro-fibrillar angle
Banana fiber	120±5.8	1350	550±6.7	20	5-6	2-5	5	11°
Sisal fiber	205±4.3	1450	350±7	12.8	6-7	12.5-17.5	11	20°
Pineapple leaf fiber	50±6	1526	413±8	4.2	3-4	-	-	14°
Glass fiber	15±5.8	2540	2500±8	56-72	3	-	-	-

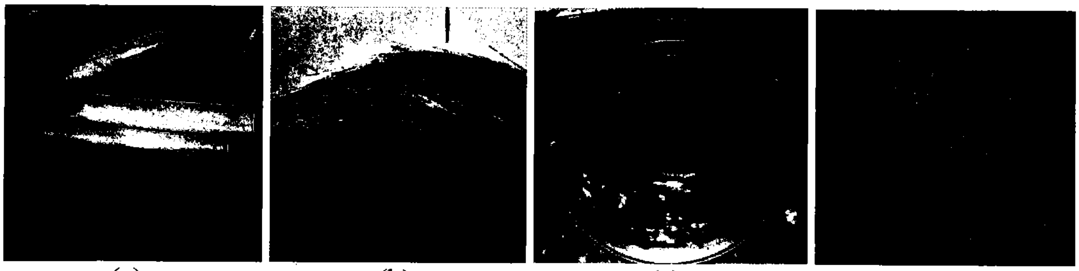
Table 2. Botanical composition of banana pseudo-stem fibers (Bilba et al., 2007).

Constituents	Cellulose	Hemicellulose	Lignin	Extractives	Moisture	Ashes
Percentage	31.27 ± 3.61	14.98 ± 2.03	15.07 ± 0.66	4.46 ± 0.11	9.74 ± 1.42	8.65 ± 0.10

METHODOLOGY

Fiber Preparation

The fibers were extracted from banana pseudo-stem after the fruit bunch has been harvested at area of Parit Raja, Batu Pahat, Johor, Malaysia. The individual layer of stem was cut and placed on the top of wood panel with even surface and fixed at one end of the stem. Then, a scrapper used to scratch the stem and then a thin plate is used to thinning the stem until threads of fiber appears and all the lignin has been removed. The threads of fiber dried under sunlight for about 12 hours until all the moisture removed from fiber. Fiber has been treated by using 5% sodium hydroxide (NaOH) solution for 4 hours and then washed thoroughly under running water and distilled water used for last wash. Fiber then dried in oven at 70 °C for 24 hours to removes moisture. Fiber was cut into short length between 2 cm to 3 cm.



(a) (b) (c) (d)

Figure 1. (a) banana pseudo-stem; (b) untreated banana fiber; (c) NaOH treatment; (d) short banana fiber after treated.

Mould Preparation

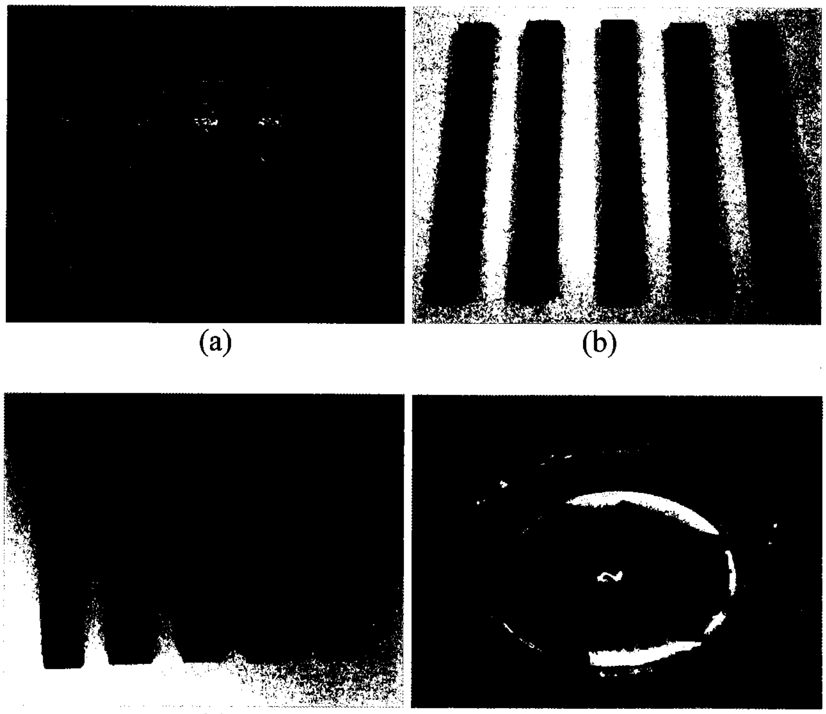
The mould prepared by using two pieces rectangular aluminum plates with dimension of 300 mm × 300 mm × 4 mm. Plate was marked by using pencil to line up the rectangular shape with dimension of 200 mm (L) × 200 mm (W). A layer of thin plastic was attached on the plate surface by using clear tape on one surface for both plates to provide better surface. Two layer of double sided tape (1.5 mm thick) was attached to get 3 mm mould height on one plate according to pencil mark. The attached double tape acts as female mould and the other plate acts as cover mould.

(a) (b) (c)

Figure 2. (a) Mould; (b) hand lay-up; (c) composites sample.

Sample Preparation

Release agent (silicone spray) was applied to the surface of mould to facilitate the removal of the finished part. Weight the fiber, epoxy and hardener according to the testing percentage. The epoxy 3554A of density 1.18 g/cm^3 and is mixed with hardener 3554B of density 1.18 g/cm^3. The weight ratio of mixing epoxy and hardener is 2:1. A layer of epoxy and hardener mixture was applied on the mould surface and put the short fiber into the mould with randomly oriented position. Then, pour remaining epoxy and hardener mixture into mould. Hand roller is used to eliminate air bubbles and to compact the material against the mould. Then, another aluminum plate is placed at the top of the mould and was pressed uniformly for 24 hours for curing in room temperature. Finally, sample was cut into specific dimension according to testing standard by vertical band saw as shown in Figure 3.



(a) (b) (c) (d)

Figure 3. Sample of (a) tensile test; (b) flexural test; (c) impact test; (d) water absorption.

Testing

The quantity of 5 specimens has been tested through each following testing:

a. Tensile test according to ASTM D638-03 with speed 5mm/min, 50mm gauge length and 3mm thickness by Universal Testing Machine (UTM).
b. Flexural test according ASTM D790-03 with 2mm/min, 48mm span length and 3mm thickness (Universal Testing Machine by Universal Testing Machine (UTM).
c. Impact test according ISO 179 (Charpy impact test).
d. Hardness test using Durometer impact tester (Type D).
e. Water absorption test according to ASTM D570 for 24 hour.
f. Scanning electron microscope (SEM) to analyze fracture surface.

RESULTS AND DISCUSSIONS

Tensile Test

Table 1 shows the increment of maximum stress or ultimate tensile strength value as the fiber percentage composition increase. Composite with 15 wt% of banana fiber shows the highest tensile strength of 34.121 Mpa. It proves that the increment of fiber percentage increased the ability of material to withstand external force. Value of Young's Modulus also shows increase pattern as the fiber percentage composition increased. The increment in Young's Modulus proves that the increment of fiber percentage composition provides better stiffness to the composites.

Flexural Test

The maximum flexural strength was also increases as the fiber percentage composition increased from 5 wt%, 10 wt% and 15 wt% with value of 12.094 MPa, 18.004 Mpa, and 20.935 MPa respectively. Maximum flexural stress indicates the ability of material to resists deformation under loads and the 15 wt% fiber in composites shows the highest resistance to deformation under loads or forces.

Impact Test

From impact testing results in Table 1, the 5 wt% fiber composition shows the lowest impact strength with impact strength of 0.231 J/mm^2, followed by 10wt% fiber composition with impact strength of 0.290 J/mm^2 and the highest value of impact energy is the 15 wt% fiber composition with impact strength of 0.343 J/mm^2. It shows that the increment of fiber percentage composition was influences the increment in impact strength. So, the fiber percentage composition affecting the impact energy with provides better impact absorption and toughness to composites.

Hardness Test

From Table 1, the hardness shore average value was increases as the fiber percentage increased because the fiber provides stiffness to the composite. At the composition of 5 wt% fiber the average hardness value is 76.4, then the value increase to 77.2 at the composition of 10 wt% fiber and 80.8 at the composition of 15 wt% fiber.

Table 1. Properties of banana pseudo-stem fiber reinforced epoxy composite.

BF wt%	Epoxy wt%	Ultimate Tensile Strength, Mpa	Modulus of Elasticity, Mpa	Maximum Flexural Strength, MPa	Impact, J/mm^2	Hardness Shore	Water Absorption Percentage, %
5%	95%	19.048	723.690	12.094	0.231	76.4	1.149
10%	90%	26.575	892.875	18.004	0.290	77.2	1.409
15%	85%	34.121	1150.098	20.935	0.343	80.8	1.536

Water Absorption Test

Table 1 shows the increment of fiber percentage in composite encourages the increment of water absorption percentage. This condition occurs because the banana fiber characteristic itself tends to absorb moisture and water.

Scanning Electron Microscopy (SEM)

Figure 4-6 shows the fracture surface of tensile test, impact test and flexural test respectively in 100 x magnificent. The SEM images shows better fiber and matrix interaction in highest fiber percentage composite. There is low stress-transfer in low percentage of fiber composition due to not enough fiber concentration. Composite with lower percentage of fiber shows more evidences of fiber debonding and fiber pull out condition. Higher fiber percentage shows better interaction between fiber/matrix and also fiber/fiber.

(a) (b) (c)

Figure 4. Tensile test fracture surface of (a) 5wt% BF; (b) 10 wt% BF; (c) 15 wt% BF.

(a) (b) (c)

Figure 5. Impact test fracture surface of (a) 5 wt% BF; (b) 10 wt% BF; (c) 15 wt% BF.

(a) (b) (c)

Figure 6. Flexural test fracture surface of (a) 5 wt% BF; (b) 10 wt% BF; (c) 15 wt% BF.

CONCLUSION

According to the testing on those different fiber percentage compositions, the increment in fiber percentage improves on mechanical properties to the composite. The composition of 15% banana fiber with 85% epoxy resin shows the best mechanical properties on the toughness, stiffness and strength through tensile test, impact test, flexural test and hardness test. But, the composition of 15% banana fiber with 85% epoxy resin shows a little low performance in water absorption test where its water absorption percentage shows the highest result compared to other two compositions. The fracture surface has been viewed through scanning electron microscope (O'Connor, 2001) and shows significant results to the mechanical and physical behaviors of the studied material. With these results, Musa Acuminata X Balbisiana Colla (*Awak*) pseudo-stem fiber reinforced epoxy composite allows further research opportunity and also shows potentiality in composite material development for industrial purpose.

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